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## The spectrum of the B[e] star BAL224.

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**Abstract.** We present optical spectroscopy of the emission line star BAL 224 ( $V=17.3$ ,  $B-V=0.46$ ). This star also named KWBBE 485, [MA93]906 is located at the periphery of the young SMC cluster NGC 330; it is known as a photometric variable with a possible period around 1 day (Balona 1992). Furthermore it was reported as the optical counterpart of the prominent mid-infrared source (MIR1) by Kucinskas et al. (2000), indicating the presence of a dust shell. The star was included in a sample of B-type stars observed using the ESO VLT-FLAMES facilities. The presence of emission lines such as Fe II, [Fe II], [S II] make this object like a B[e] star. The  $H\alpha$ ,  $H\gamma$  and  $H\delta$  lines show an asymmetrical double-peaked emission profile suggesting the presence of an accretion disk. Moreover the MACHO and OGLE light curves were analyzed; in addition to a long-term variability ( $\simeq 2300$ d), a short period very close to 1 day has been detected using different methods, confirming the variability previously reported by Balona (1992). Finally the nature of this object is reconsidered.

### 1. Spectroscopic observations

Two spectra of BAL224 ( $\alpha(2000)$ ,  $\delta(2000)$ : 00h 56mn 06.45s,  $-72^\circ 28' 27.70''$ ) were obtained at medium resolution in setups LR02 (396 - 457 nm,  $R=6400$ ) and LR06 (644 - 718 nm,  $R=8600$ ). They are dominated by the 2-peak emission components of Balmer lines which are strongly asymmetric with  $V \gg R$ . Due to the resolution used it was possible, for the first time, to identify emission lines of [FeII], FeII, [CrI] as well as nebular lines [SII]6717, 6731 (see Fig 1). The mean radial velocity of these lines (RV) is  $154 \text{ km s}^{-1}$ . The FWHMs of metallic emission lines are about  $100 \text{ km s}^{-1}$  and correspond to the instrumental broadening. The low S/N ratio in the continuum ( $S/N \simeq 20$ ) did not allow to measure the radial velocity of HeI lines present in the spectra of BAL224. The RVs mean values of the shell component of  $H\alpha$ ,  $H\gamma$  and  $H\delta$  (see Figs 1, 2 and Table 1) is  $187 \text{ km s}^{-1}$ .

### 2. Photometric Variability

According to Balona (1992), this star displayed fading of 0.2 mag and periods close to 1 day but none of these periods could fit satisfactorily the data. Thanks

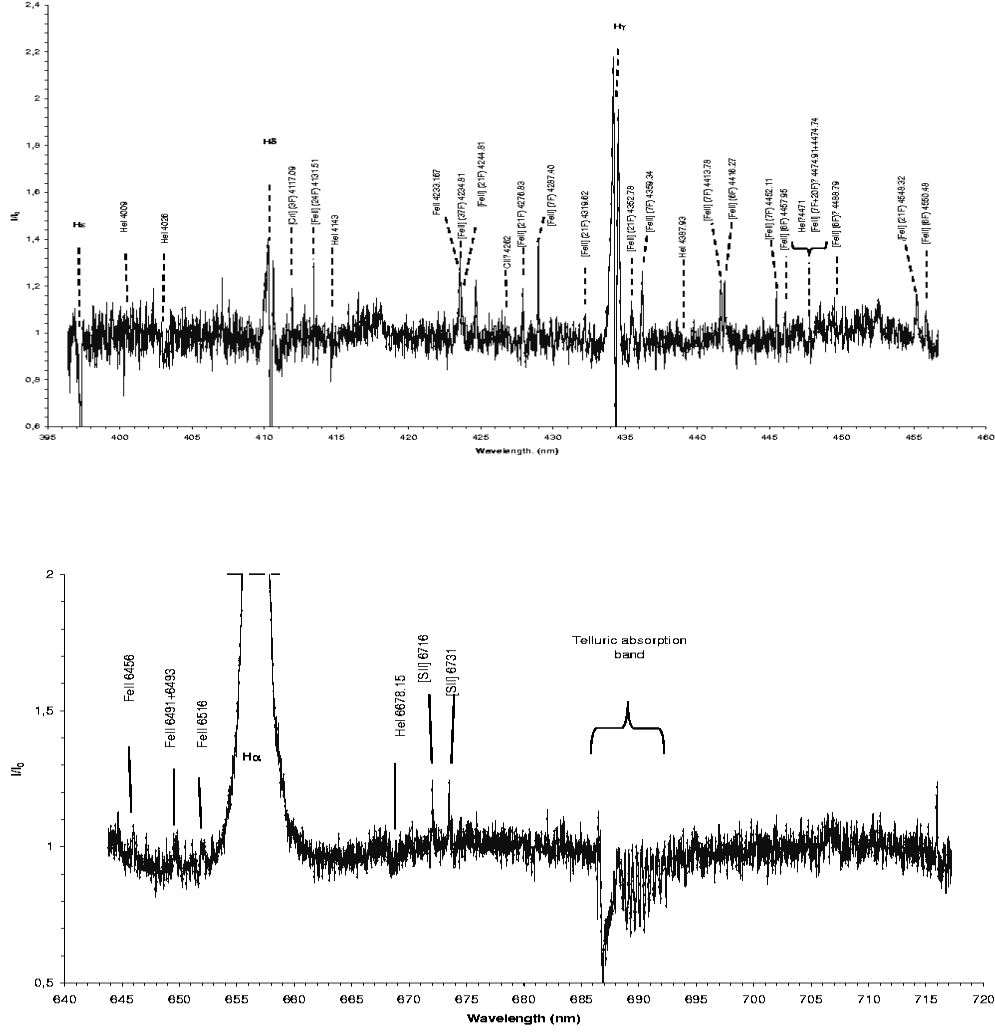


Figure 1. Top: Spectrum of the BAL224 in the LR02 VLT-GIRAFFE setting (R=6400). Bottom: Spectrum of the BAL224 in the LR06 VLT-GIRAFFE setting (R=8600).

to the MACHO and OGLE databases, 2 strong bursts (Fig. 3) could be observed with an amplitude of 0.4 mag on a time scale of about 3100 days. Between these 2 strong bursts, smaller ones which do not seem to be periodic could also be observed. We searched for short-term variability and like in Balona (1992) we find periods close to 1 day which do not give a satisfactory fit of the data. But irregular short- and long-term variabilities may also be explained by the presence of a multiple object.

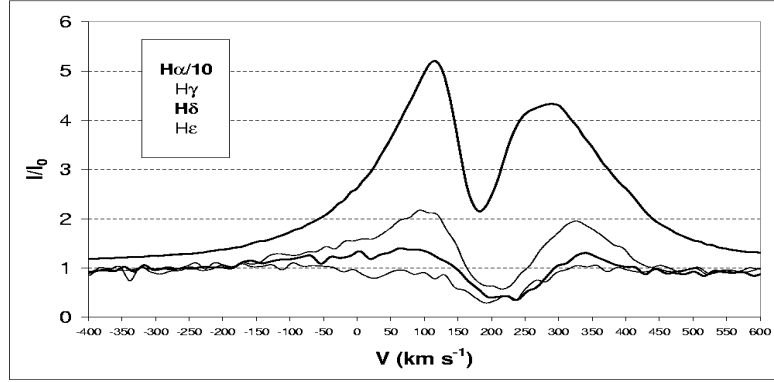
Figure 2. Radial velocities of H $\alpha$ , H $\gamma$ , H $\delta$  and H $\epsilon$  for BAL224.

Table 1. Observational indications such as radial velocities or intensities of lines in the spectra of BAL224. The values between brackets come from Hummel et al. (1999).

	H $\alpha$	H $\gamma$	H $\delta$
RV <sub>V</sub> ( $\pm 20$ ) km s <sup>-1</sup>	104 [140 $\pm 50$ ]	86	62
RV <sub>shell</sub> ( $\pm 20$ ) km s <sup>-1</sup>	171	198	204
RV <sub>R</sub> ( $\pm 20$ ) km s <sup>-1</sup>	276 [301 $\pm 50$ ]	317	327
FWHM ( $\pm 20$ ) km s <sup>-1</sup>	320 [443 $\pm 50$ ]	410	600
I <sub>V</sub>	41.8	2.2	1.4
I <sub>R</sub>	33.4	1.9	1.3
Mean I	37.6	2.1	1.4
EW ( $\pm 20$ ) Å	360 [202 $\pm 20$ ]		
Ratios	H $\gamma$ /H $\alpha$ =0.055	H $\delta$ /H $\alpha$ =0.036	H $\delta$ /H $\gamma$ =0.66

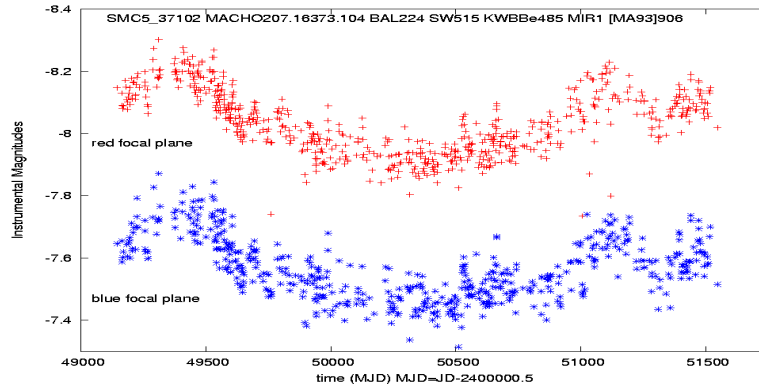


Figure 3. Light-curve of BAL224 from MACHO database.

### 3. On the nature of BAL224

From VLT-FORS1 low resolution spectroscopic observations Hummel et al. (1999) suggest that the absence of emission in HeI lines and the strong Balmer decrement can indicate that this star has a shell with a gas cooler than 5000K. Kucinkas et al (2000) thanks to their photometric study found a strong mid-IR excess compatible with a dust shell with a very low temperature: 360K. This infrared excess is compatible with B[e] and Herbig stars but the temperature determined is not compatible with B[e] stars. We confirm a strong Balmer decrement. No emission components can be observed on HeI lines and some lines of neutral elements such as [CrI] are present so we can conclude that a cool dust shell is present (Table 1, Figs 1, 2). The presence of FeII and [FeII] and their FWHM lower than  $100 \text{ km s}^{-1}$  are common points between B[e] and Herbig B[e] stars. But, we find an  $\text{EW}(\text{H}\alpha)$  smaller than  $1000 \text{ \AA}$ , which does not correspond to a B[e]. The  $\text{H}\alpha$  spectrum seen in Hummel et al (2000) and in this study clearly shows a strong asymmetric double peak which may be explained by an accretion disk (Fig. 2). This type of disk is a main characteristic of Herbig objects. Moreover, the short- and long-term irregular variabilities are characteristic of Herbig objects which may be explained by an aggregate of stars. Properties of B[e] supergiants, HAeBe and isolated HAeBe (or HB[e]) are compared with properties of BAL224 in Table 2. From this comparison, **we propose BAL224 as an isolated Herbig B[e] object.**

Table 2. Comparisons between properties of: a B[e] supergiant (Sg), a Herbig Be (HAeBe), an isolated Herbig Be or HB[e] and BAL224.

Properties	B[e] Sg	HAeBe	HB[e]	BAL224
FeII and [FeII] lines in emission	Yes		Yes	Yes (this study)
FWHM FeII, [FeII] $< 100 \text{ km s}^{-1}$	Yes			Yes (this study)
EW $\text{H}\alpha > 1000 \text{ \AA}$	Yes			No (this study + Hummel et al. 1999)
Near or far IR excess	Yes	Yes	Yes	Yes (Sebo & Wood 1994)
IR excess, $T_{\text{envelope}} > 1000 \text{ K}$	Yes			No (Kucinkas et al. 2000)
Excretion disk	Yes			No (this study + Hummel et al. 1999)
In obscure region		Yes		No (Balona 1992)
A-type or earlier + emission lines		Yes		Yes (this study + Hummel et al. 1999)
Star illuminates nebulosity in immediate vicinity		Yes	Yes	?
Accretion disk		Yes	Yes	Yes (this study + Hummel et al. 1999)
Irregular variations		Yes	Yes	Yes (this study + Balona 1992)
Isolated object			Yes	Yes (Balona 1992)
Center of small aggregates of low-mass stars			Yes	?

### References

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MACHO database, <http://www.macho.mcmaster.ca/>  
OGLE database, <http://bulge.princeton.edu/ogle/>